"Note upon Descending Intrinsic Spinal Tracts in the Mammalian Cord." By C. S. SHERRINGTON, M.A., M.D., F.R.S., and E. E. LASLETT, M.D. Vict. Received November 5,—Read November 27, 1902.

In the course of experiments upon the paths of nervous conduction in the spinal cord of the mammal, one of us observed* very numerous and wide departures from the fourth so-called "law" of Pflüger. That "law" states that "Reflex-irradiation in dem Rückenmarke nach Oben, resp. Vorn, gerichtet ist; also gegen die Medulla oblongata."† The observation of the above-mentioned exceptions rendered desirable a search for more detailed evidence of intrinsic spinal paths running in the aboral direction. We therefore set about inquiring into the existence of spinal paths connecting the activity of segments situate nearer the head with segments lying further from the head. Such evidence is obtainable with some experimental difficulty, but it has been eventually forthcoming, and amounts to demonstration of the microscopic course of the channels involved. It is some main features of these latter that we desire to record in the present communication.

METHOD.

The method employed has been that of the Wallerian nerve-fibre degeneration, but with a novel feature in the mode of application of the method. For the purpose in view the ordinary establishment of a cross-lesion in the spinal cord is futile. The secondary degeneration then produced befalls, in the spinal region under investigation, all nerve-fibres having their perikarya headward of the cross-lesion, whether those perikarya lie in the cerebral hemisphere, basal ganglia, mid-brain, cerebellum, bulb, or cord itself. It is obviously then impossible to identify which particular ones, if any, of the degenerate nerve-fibres are coming from the cord-segments whose nerve-tracts are the special object of inquiry. To obviate this difficulty, we have adopted a method which may be termed a method of "*successive degeneration.*" The method consists in producing two or more successive degenerations with allowance of a considerable interval of time between them. In the piece of cord to be examined, a first degeneration is allowed time enough to remove all the tracts descending from sources other than those the immediate object of inquiry. This is a procedure which requires in our material, at shortest, 9 or 10 months to complete. When the time is complete, the cord is left, as it were,

* "Croonian Lecture," 'Phil. Trans.,' B, 1897.

† 'Die sensorischen Functionen des Rückenmarks der Wirbelthiere, nebst einer neuen Lehre über die Leitungsgesetze der Reflexionen' (p. 73), Berlin, 1853.

like a cleaned slate, on which once more a new degeneration can be written without fear of confusion with a previous one. The cord is then ready for receiving the lesion which shall cause degeneration of the particular tracts whose existence is suspected. After a period suitable for the full development of the new degeneration, the cord is treated histologically by the Marchi method, and the microscopical examination proceeded to. This method resembles in principle a method employed with noteworthy results by Münzer.* This author performed on the new-born rabbit a first lesion (*e.g.*, removal of one cerebral hemisphere, injury of mid-brain or cord), and later, in the animal when grown, proceeded to establish a new lesion which was thus uncomplicated by the part already separated: thus "Gudden's *agenesic* atrophy" was made to precede the degeneration desired for study.

One of the experiments made by Münzer and Wiener (1895) deals with the problem undertaken by ourselves. After semi-section of the spinal cord of the new-born rabbit at the last dorsal segment, they performed total transection two segments further back when the animal was grown. Behind the second section they found "as many fibres degenerate on the semi-sected side as on the intact side." If not "decussation fibres" these fibres must evidently be of intra-spinal origin in the anterior lumbar region. As to their being decussation-fibres, Münzer says they are, on the contrary, from the grey matter of the same side as the semi-section, a statement which our own results in the dog in the same and other regions endorse.

In our experiments the cord of the dog has been used, and total transection has not been the final, but the first step in the procedure. This course was chosen in order to completely exclude all chance that fibres from sources not the object of inquiry could complicate the second lesion. In order to ensure complete transection, we have in almost all our experiments exsected and ablated a short segment of the cord, instead of simply severing it across. The exsection was made immediately in front of those spinal segments whose system of descending fibres in the cord was to be looked for. Then after an interval, which we found by experience must not fall short of 260 days, the second lesion, usually some form of partial section, was performed, and a further period of about 20 days was allowed for degeneration. The procedure of total transection prior to the lower limiting lesion has an additional advantage in the lesser interference with the local circulation of the cord in the final lesion. Better in these respects this plan offers, however, considerably greater difficulties than its converse. We have, in spite of all care, lost a number of experiments in the long intervals necessary to elapse while

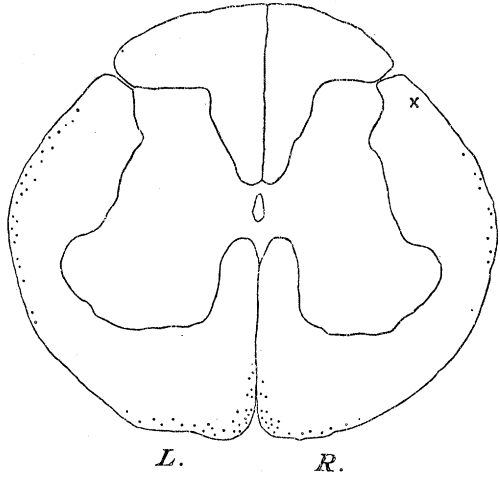
* E. Münzer, with Wiener, 'Prager Medicin. Wochenschrift,' 1895; also 'Monatschr. f. Psychiat. u. Neurol.,' vol. 12, p. 241, 1902.

the cord is ripening for the second operation. We have, however, obtained thirteen successful complete experiments: in these the shortest interval has been 260 days, the longest 568 days. Among these is included two in which, for special reasons, the partial cross-lesion of the cord was made precedent to the total transection.

Results.

The spinal segments examined as sources of aborally-running fibre-systems have been posterior cervical, anterior thoracic, mid thoracic, posterior thoracic, and anterior lumbar. From all these regions our experiments demonstrate that copious aborally-running fibre-systems spring. Thus, the accompanying fig. 1 shows, for instance, tracts of fibres in the 5th lumbar segment which have their origin in cells of the 2nd thoracic segment.

Fig. 1.



Cross-section of the cord of the dog at a level in the anterior part of the 5th lumbar segment; Marchi preparation. The section reveals the topography at that level of the aborally-running fibre-system of the 1st and 2nd thoracic segments. The 8th cervical segment of the cord had been completely exsected and ablated. A partial translesion (rather more than a semi-section) was made the left half of the 3rd thoracic 568 days subsequent to the removal of the 8th segment. The exact extent of this second lesion was determined subsequently by microscopic examination in serial preparations, and its limits will be described and figured in a fuller communication. The dots indicate, in a way mentioned in the text (p. 120), the density and extent of the degenerate tracts of fibres. L = left side; R = right side.

Speaking generally, of the fibres composing the aborally-running systems springing from the grey matter of the spinal segments

examined, we find there may be distinguished two sets. For physiological description it is in some ways convenient to regard the length of the spinal cord as divisible into regions; thus, a brachial for the fore limb, a thoracic for the trunk, a crural for the hind limb, a pelvic for pelvic organs, a caudal for the tail, and so on. A reflex initiated *viâ* an afferent path of one such spinal region may evoke its peripheral effect by efferent paths of a spinal region other than that to which the original entrant path belongs. Such a reflex has in a former paper by one of us* been termed a "long" spinal reflex, in contradistinction to reflexes whose centripetal and centrifugal paths both belong to one and the same spinal region. The latter reflex it was proposed to term "short."† Analogously, in the aborally-running fibre-systems of the spinal segments examined, by our experiments fibres of two categories are found, one a set passing beyond the limits of the spinal region in which they arise, the other not passing beyond those limits. The former we would term "long spinal," the latter "short spinal" fibres. In each of these main categories there can be distinguished fibres of various intermediate length.

Again, the fibres of each of the above two categories may be classified into two sets or tracts, according to their topography relatively to the cross-section of the cord. Fibres of both of the above categories are situate both in the lateral columns and in the ventral columns of the cord. It is useful, at least for descriptive purposes, to indicate this by terminology. We thus recognise in the aborally-running intrinsic spinal fibre systems the following sets or tracts: (α) *Ventral short fibres*, (β) *ventral long fibres*, (γ) *lateral short fibres*, (δ) *lateral long fibres*. It must be added that the distinction into lateral and ventral is somewhat artificial, as there exists often, especially in the case of the "short" fibres, no distinct gap between the ventral and lateral fields of distribution of the fibres in the transverse area of the cord.

In regard to the "long" fibres, we find that in all the regions examined by our experiments there is no evidence of decussation of these tracts. This statement does not exclude the possibility that the collaterals or the fine ultimate terminals of these fibres may in some cases penetrate in the grey matter across to synapses in the crossed side of the grey matter. We have at present no reliable microscopical evidence for or against such a possibility. But all our evidence is consentient that the fibres themselves do not pass from the white columns of one side of the cord into those of the crossed side, that is, do not in the ordinary sense decussate.

A similar statement seems also to hold true for the "short" fibres, thus confirming Münzer:‡ it is certainly true of the majority of the

* C. S. Sherrington, "Croonian Lecture," 'Phil. Trans.,' 1897.

† *Ibid.*

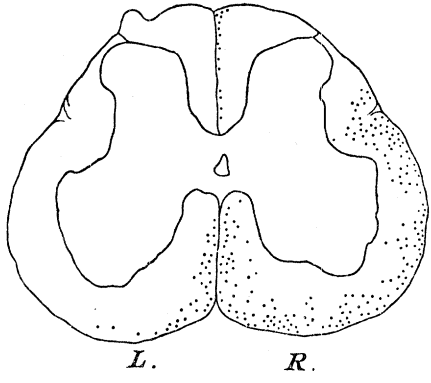
‡ 'Prager Medic. Wochenschr.' 1895.

short fibres; but analysis of our material makes us hesitate to positively affirm that it is true for all of them. A small proportion of the short fibres *may* decussate, at least in the sense that short fibres arising in perikarya belonging to one lateral half of the cord may find their way into the white ventrolateral columns of the crossed half. We do not affirm, however, that any of even our "short" fibres do decussate, we simply affirm our present inability to deny that a small proportion of them may do so.

Some of the "long" fibres are very long, both in the lateral and in the ventral columns of the cord. Thus, some of those arising from perikarya in the 6th and 7th cervical segments we have traced into the sacral region, *i.e.*, through nearly thirty spinal segments, both in the lateral and in the ventral columns. The rule pointed out by one of us in a previous paper,* that the long fibres in the spinal cord tend to lie nearest the surface of the cord, is well exemplified in these intrinsic spinal systems.

Besides fibres in the ventrolateral columns the aborally-running fibre-systems of spinal origin include fibres in the dorsal columns.

FIG. 2.

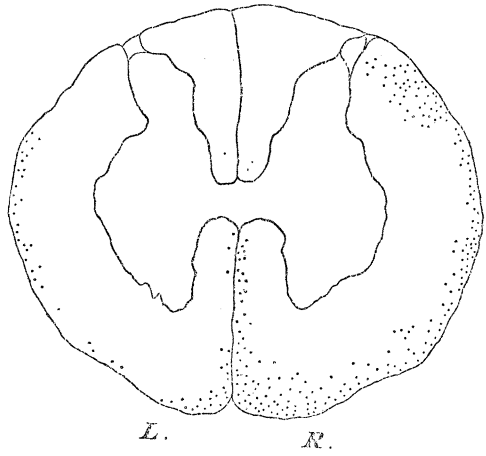


Cross-section of the spinal cord of the dog at the level of the 1st sacral segment; Marchi preparation. The section reveals the topography at that level of the aborally-running fibre-system of the nerve-cells of the 1st and 2nd lumbar segments. A short length of the 13th thoracic segment of the cord had been completely exsected and ablated. A partial translesion (rather more than a semi-section) was then made through the right side of the 2nd lumbar segment in its anterior levels 290 days subsequent to the total exsection. The extent of this second lesion was accurately determined later by microscopic examination in serial preparations; its exact limits will be described in a fuller communication. The dots indicate, in the way mentioned in the text, the density and extent of the tracts of degenerate fibres. L = left side; R = right side.

* 'Journ. of Physiology,' vol. 14, p. 298. Cambridge and London, 1893.

These are less numerous. We defer detailed description of them, together with further detailed description of the ventral and lateral tracts above-mentioned, until a fuller communication dealing with the whole subject. The general features of the topography can be gathered better from the two accompanying figures than from any even lengthy

FIG. 3.



Cross-section of the spinal cord of the dog at the level of the anterior part of the 4th lumbar segment: Marchi preparation. The section reveals in left half of the cord the topography at that level of the aborally-running fibre-systems arising in perikarya of the grey matter of the left half of the 6th and 7th cervical segments. Total transection of the cord had been performed through the 8th cervical segment 268 days subsequent to left semi-section at the 5th cervical segment. Thirteen days only was allowed for the development of the degeneration after the second lesion. The degeneration may not therefore appear so extensive as it might have done later, but its localisation is probably the more precise. The exact extent of the semi-section was found by subsequent microscopic examination in serial preparations to amount almost accurately to a full section of the left half of the cord; the detailed limits will be described in a fuller communication. The degeneration in the right half of the lumbar cord figured includes aborally-running fibres derived not merely from the spinal cervical grey matter, but from bulbar and cerebral cources as well; and these are practically inextricably commingled one with another. The dots signify, in the way mentioned in the text below, the density and extent of the degenerations. L = left side; R = right side.

textual description. All the figures have been drawn with the camera lucida upon squared proportional paper, and the squares on the paper have been made to correspond with squares in an engraved eye-piece. All the drawings are to exactly the same scale. The dots signify degenerate nerve-fibres, but the number of dots does not of course represent the absolute number of degenerate fibres, but falls far short

of it. Extreme care has been taken, however, to make the number of the dots bear fairly accurately a general proportion to the density of the degeneration, and the same proportion in one drawing as in another.

"The Inter-relationship of Variola and Vaccinia." By S. MONCKTON COPEMAN, M.A., M.D. Cantab., F.R.C.P. Communicated by LORD LISTER, F.R.S. Received November 13,—Read November 27, 1902.

The term "variolæ vaccinæ" employed by Jenner, as a synonym for cow-pox, has been generally accepted as affording evidence that in so naming this disease, "small-pox of the cow," he was desirous of placing on record his belief that cow-pox, or vaccinia, was intimately related to human small-pox, if indeed it were not directly derived from it.

This theory, however, appears to have found but scanty favour in Jenner's day, and even at the present time the value of the practice of vaccination is, by some, impugned on the plea that inoculation of one disease—cow-pox—could not be expected to exert any really protective influence against the ravages of small-pox—a disease considered by them of totally different origin.

In the hope of obtaining definite information on the subject, many observers, during the long period which has elapsed since the introduction of vaccination, have set themselves the task of attempting to solve, by experimental methods, the problem of the true relationship of vaccinia to variola.

These attempts have been, for the most part, directed to the possibility of giving rise to cow-pox by the introduction, in one or another manner, of the virus of small-pox into the system of the bovine animal. In the great majority of such attempts, which have been much more numerous than is generally supposed, the results have been entirely negative, although so numerous have been the experimenters, who from time to time have attacked the problem, that the total number of instances in which an apparently successful result has been obtained, is now considerable.

So far as I am aware, the first recorded experiments are those of Gassner of Gunsberg, who, in 1801, succeeded, after no less than ten fruitless attempts, in directly variolating a cow with small-pox virus. The lymph thus obtained was employed for the vaccination of four children, from whom other seventeen were subsequently vaccinated. None of these exhibited any signs of small-pox.